



Review Article

Zonification for medical purposes in NBC incidents

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ABSTRACT

In any anatomic, biological or chemical (NBC) accident or incident, the casualties are either treated on the spot or evacuated to health care centers. In the case of an NBC incident, the evacuated casualties must also undergo decontamination before they are referred to non-contaminated health care facilities. The present paper proposes a health care zonification model for NBC incidents of any magnitude in which the casualties are treated, stabilized classified and decontaminated so as to be referable to health care centres. The model establishes the need for on-the-spot medical care within the "hot" zone with an adequate level of protection and the need to set up a contamination control checkpoint, and suggests the need to establish a holding area preceding the admission to the NBC Decontamination Station and other health care facilities, termed the "Emergency Treatment Station", in which the casualties of an NBC incident may be stabilized, classified and treated.

Key Words: *Intervention zone. Health care zonification. Hot zone. NBC incident.*

RESUMEN

Zonificación sanitaria en incidentes NBQ

En un accidente o incidente NBQ los afectados son atendidos en el lugar del suceso o son evacuados a los centros sanitarios. En un incidente NBQ, además es necesario descontaminar a los afectados antes de la entrada a las instalaciones sanitarias no contaminadas. Este trabajo propone un modelo de zonificación sanitaria para incidentes NBQ de cualquier magnitud, donde los afectados sean tratados, estabilizados, clasificados y descontaminados para poder ser evacuados a los centros sanitarios. En él se establece la necesidad de realizar la atención sanitaria dentro de la zona caliente con el nivel de protección adecuado, se establece la necesidad de activar un punto de control de la contaminación y se postula la necesidad de establecer un área previa a la entrada en la Estación Sanitaria de Descontaminación NBQ (ESDNBQ) e instalaciones sanitarias denominada Estación de Tratamiento de Emergencia (ETE) donde estabilizar, clasificar y tratar a los afectados por un incidente NBQ.

Palabras clave: *Zona de intervención. Zonificación sanitaria. Zona caliente. Incidente NBQ.*

INTRODUCTION

If a nuclear, biological or chemical (NBC) incident were to occur an emergency services response system would be activated in order to reduce or minimise the consequences. We may be inclined to think that the quicker the response, the less impact the consequences will have on the affected individuals and the environment. However, the reality is not so straightforward. In all cases, the staff that intervene should have:

- The appropriate professional qualifications and training.
- A set of procedures and standard protocols that are put into action when responding to any kind of situation at any time.

– The resources and equipment needed to respond to the incident.

These facts should be taken into consideration because self protection should take priority over intervention^{1,4}. These procedures and intervention protocols should establish an incident control system, the zones that the affected area should be divided into, and the relationship between the different emergency services and those who are responsible for setting up the intervention area, in order to avoid overlapping and to improve response capabilities. All intervening personnel should be made aware of the intervention area and the different zones that have to be set up as a result of the incident^{5,6}.

One of the main problems that we face when dealing

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Received: 10-4-2007
Accepted: 29-5-2007

with the zonification of a NBC incident is that the emergency teams use different names to refer to the separate areas that are created for them to work in. Furthermore, people are often unaware of or simply ignore the medical implications associated with a NBC incident, such as establishing levels of individual protection, carrying out contamination control procedures, or setting up decontamination procedures for those affected in specially built medical facilities.

In light of these facts we should consider a proposal about how medical zones in a NBC incident should be organised, both in accidents with a small number of affected individuals and in those with multiple casualties (massive casualties in military settings). This organisational proposal would make comprehensive medical care for those affected a priority and would optimise the available resources in an emergency situation where contaminating NBC agents are present.

The aim of NBC incident response is to limit the consequences for people and the environment; therefore a response system should be established that includes the coordination of emergency services to allow the following to be done in the shortest amount of time^{7,9}:

- Detect/identify the contaminating agent.
- Evaluate the risks with the aim of eliminating them.
- Protect the zones that have not been affected by the incident by setting up a safety perimeter (exclusion zone) in order to isolate the danger zone.
- Rescue and remove the individuals affected.
- Decontaminate the individuals affected.
- Set up medical treatment for casualties.
- Evacuate those affected and provide them with safe areas to stay in on a permanent or temporary basis.

The following points should also be added from a medical NBC perspective:

- Limit the effects the accident/incident could have on people and environment.
- Prevent contagion of the whole rescue team.
- Decontaminate the affected individuals before they enter medical facilities.
- Assure first aid before individuals are transferred to a hospital or are discharged depending on the needs of those affected by the incident.

Given the variety of unusual elements that make up an NBC incident the response is multidisciplinary and therefore a comprehensive response program which is recognised by all intervening (and non-intervening) staff must be established.

INTERVENTION AREA

The problem currently considered is the fact that each emergency team uses its own set of terms to describe the areas that are created when a NBC incident takes place. For example, it is common for the words "sectorisation" or "zonification" to be used to refer to the different areas that an incident is divided into, however, the problem is that despite being a word that is used in emergency circles, "sectorisation" has not been included in the *Diccionario de la Real Academia Española de la Lengua* (Royal Spanish Academy Dictionary) (22nd Edition).

Even though nowadays terms such as hot zone, warm zone and cold zone have been established to refer to the different sections that an affected area is divided into regardless of the incident, this terminology is not consistent with the official terminology used by some emergency teams. Spanish legislation that deals with preparatory measures associated with the risk of accidents involving the transportation of dangerous goods by road or rail, considers the intervention zone of an accident to be that where the consequences are most evident or where we can anticipate that people, property or the environment may be harmed and where protective measures need to be put into practice immediately. This thereby extends the concept of the intervention zone to the area where the consequences of the accident can lead to a certain level of harm which justifies the immediate introduction of protective measures. The intervention area is different from the area known as the warning zone, which is the area where the consequences of the accident may have an impact that the population is aware of, however intervention is not justified, except in the case of critical groups of the population¹⁰.

This classification is broader within the context of civil protection and three clearly outlined areas are established known as: the intervention area, the aid area and the base area. The intervention area is the area for evaluating casualties. This is where the operating intervention groups and medical rescue teams carry out their work. The aid area is next to the intervention area and here medical care is provided and different levels of support are organised for operating intervention groups. The base area is where the reserves can assemble and organise themselves. It can also be an area for receiving evacuated individuals before they are sent out to shelters^{11,12}. The fire service also uses this classification system but instead of employing the term aid area, they prefer the concept "support area". This area is subdivided into a restricted access sub-area and a free access sub-area. The contamination perimeter, the safety perimeter and the isolation perimeter are located around the intervention, support and base



areas respectively and their distance from the central point depends on the contaminating agent and the predominant weather¹³. However, medical services only outline two different areas to carry out their work. The intervention area is known as the rescue area and this is the area where the search and rescue teams operate. The zone that is further away from the area where the accident has taken place is known as the aid zone and this is the physical area where the medical services are based^{14,15}.

From a military perspective, two different areas are established prior to a NBC attack. The first is an attack zone which is the area that is immediately affected by a NBC contaminating agent. The second is the danger zone which is the area that is most likely to be exposed to the NBC agent because of the wind that could carry it in that direction¹⁶.

Given that different concepts have developed different names, it is preferable to use a common set of terms and therefore the attack area, danger zone, intervention, warning or rescue zone should be known as the hot zone. The aid area or zone and the support zone should be referred to as the warm zone and the base area can be referred to as the cold zone.

From a NBC perspective the hot zone concept is defined as the area closest to that of the incident (and the area affected by the spread of the agent depending on the wind), which needs to be broad enough to prevent an adverse impact on the population given that the agent can contaminate the environment. The hot zone is also known as the contaminated zone, the dirty zone, the exclusion zone or the restricted zone.

First of all, a circular area with a variable radius depending on the contaminating agent and the dominant weather is established around the site where the emission, spillage or attack has taken place. The radius of this initial exclusion zone depends on the type of contaminating agent and its concentration, the time the incident took place, the weather conditions at the time the dissemination took place and the weather during subsequent hours, and the place where the emission occurred and its orographic conditions. The hot zone will initially be circular area the size and shape of which will depend on wind speed.

The main problem is that during the initial stages of an accident many of the factors involved in creating this initial exclusion zone are unknown and it is necessary to establish a preliminary safe distance in order to organise the zonification of the incident. This is of the utmost importance given that we were obliged to wait until the circular no. 50 was published which established that the radius of the hot zone for a terrorist incident that included NBC agents should be 150 metres or more (according to TEDAX-NRBQ [Spanish national police service])¹⁷. However, authors like Shidell, Pa-

trick and Dashiel believe that the exclusion distances in cases involving chemical or biological accidents should never be less than 90 metres around the area closest to the incident (90-1000 m) and 1,800 metres windward from the place where the emission occurred¹⁸. Whereas Cashman believes that this distance should not be less than 200 to 300 metres if we are dealing with an incident involving chemical or biological warfare agents¹⁹. Nevertheless, the most important factor when trying to accurately determine the radius of the hot zone from the origin of the incident is to identify the type of agent and its concentration in the shortest amount of time possible in order to evaluate the level of contamination and the amount of individual protection needed²⁰. If we compare the distances that have been applied to chemical or biological incidences to the exclusion distances in accidents involving flammable chemicals, we can see that the initial demarcation of the intervention zone (hot zone) ranged from 50 to 300 metres or even 600 metres, depending on the whether there was a risk of explosion or not, if a fire had broken out or if incident had taken place inside or outside a building^{21,22}.

A line that follows the direction of the wind and begins where the incident took place is established in order to calculate the dispersion of the cloud that is produced and then displaced by the wind. However, the dispersion depends on the wind speed (W_s). Thus, if the wind does not blow ($W_s \leq 10$ km/h), the dispersion will be circular, whereas if the wind speed is over 10 km/h the contaminating agent will be moved in the direction of the wind and will take on a geometric shape like an ellipsoid (depending on the concentration of the contaminating agent). Given the difficulty involved in creating a graphic image by hand (this is not the case when using a computer) a prediction is made about the movement of the funnel or triangular-shaped cloud which is known as funnel, bulbous or plume shaped cloud dispersion. The rounded shape of the vertex corresponds to the initial exclusion circle, the sides are the tangent lines to the exclusion circle and the angle of these lines depends on the wind speed²³.

The dispersion angle varies depending on the wind speed. If W_s is > 10 km/h, then the dispersion angle will be 30° on each side of the line of the wind direction, whereas if the W_s increases, the dispersion angle will decrease to 15° ²¹. In contrast, the 1996 North American Emergency Response Guidebook states that the funnel shaped cloud dispersion has a 20° angle on each side of the wind line there by allowing the creation of a simple graphic image using the diameter of the circle of the warm zone as a reference²⁰. The maximum distance travelled by a cloud depends on the agent, its dispersion characteristics and the weather conditions^{9,16,24}.

Access to this area should be restricted to people with the appropriate training and individual protection against the contaminating agent²⁵⁻²⁸. The warm zone is established around the hot zone and follows its shape and then the cold zone is established around the warm zone. This system has been accepted by the Spanish National Security Forces who acknowledge these distances and established terminology. Similarly, the Spanish police force also refers to each area as the target area, first band and the second band (depending on the police unit in charge of the zonification). The Spanish Civil Guard create a sub-zone in the hot zone which is called the “maximum risk zone” and coincides with the area around the incident²⁹.

The warm zone is also known as the reduced contamination zone or the decontamination zone or the aid zone. This is the area where medical care is provided and where the emergency services are stationed. The aid zone is situated windward from the incident and is at least 50 metres wide³⁰. Access into and out of the hot zone is through a specific point in order to monitor those affected as a group (whenever possible). This method also improves the safety of the central area and the flows of people that head towards the medical centres can also be controlled better³¹. The medical services can be found in this area and as its name indicates, this is the area where decontamination takes place. For this reason, the decontamination facilities for affected individuals and the intervening staff are based here. The forward command post is also located in this area. Given that contaminated staff may enter this zone, everyone should have the correct level of individual protection.

The cold zone, clean zone, base area or green zone is the area that is furthest away from the incident. This can be found outside the warm zone. Individual protection is not necessary in this area, although the level of safety should be increased to help the emergency services move around in this area. The command and coordination post, the press room and the support area for the emergency services can be found in this here.

In order to outline the different areas, it is necessary to cordon off or mark the area of the incident (physical separation is better). The benefits of this method have a direct impact on the intervening personnel because it improves the organisation and management of the different emergency services and makes it easier for those in charge to monitor and evaluate the situation.

Despite the fact that in an ideal situation medical care would be based in the hot zone, in general, medical personnel do not have access to it. Sometimes this is because they do not have the appropriate protection and at other times it is be-

cause they do not have authorisation to enter the hot zone. In this case, the intervening non-medical staff should remove the individuals affected that are not capable of leaving the area un-aided. In order to do this the operating groups (security forces, fire service, emergency teams) will receive instructions from medical staff about basic aid techniques and how to classify those affected in a simple way in order to remove them from the area of the incident³¹. If medical professionals enter the hot zone with the appropriate protection they can help to remove individuals, begin treatment if it is available, organise a classification system for affected individuals according to predetermined medical criteria (the criteria for emergencies or massive casualties) and prioritising individuals for evacuation^{32,33}.

In short, the importance of correct zonification is illustrated in the following example. During the accident in Bhopal (India) in 1984, which was the result of a methyl isocyanate leak in an insecticide factory, 3,500 died and the same number of people were in critical condition. Approximately 150,000 people required medical treatment. The long term consequences of this accident included blindness, mental disorders, and hepatic and renal lesions. The main problem was that those who were affected and were evacuated were once again exposed to methyl isocyanate because one of the evacuation routes passed through a toxic cloud³⁴.

ORGANISATION OF THE MEDICAL ZONE

The intervention strategy is linked to the efficient organisation of the area where the incident occurs^{35,36}. The medical area is set up in the reduced contamination or warm zone in a place indicated by those in charge. The medical area in a NBC incident should adapt itself to the unique characteristics of the situation which may include: a large number of affected individuals, the significant possibility that they may be contaminated and their specific treatment needs. In short, this is a real challenge for the emergency systems that have to respond to this type of situation^{37,38}.

In Tokyo, affected individuals tended to head towards medical centres and facilities and so the need to control the flow of casualties in order to prevent the contamination of intervening medical personnel was made a priority³⁹⁻⁴¹. An access channel that individuals could use to reach the forward medical command post (Figure 1a) was considered necessary. It is preferable to establish a funnel-shaped access channel rather than an access strip given that it is easier to guide individuals who are disorientated with fewer resources and medical staff towards the aid zone using this approach.



The main problem is that in a NBC incident, all of those affected are considered to be contaminated^{42,43}. Therefore the need arises to establish a place that is located windward of the incident before the forward medical command post where contamination levels can be reduced until they reach manageable levels which do not pose a threat to the individual or others⁴⁴. This is the place where the NBC Decontamination Station is located and the treatment of affected individuals becomes the responsibility of medical personnel. Therefore this place is classified as a medical area and will be known as the NBC Medical Decontamination Station where casualties with signs of symptoms of contamination are decontaminated in special facilities (Figure 1c)⁴⁵⁻⁴⁷. This situation becomes even more complicated when we begin to include injured individuals who are also contaminated⁴⁸. Medical emergencies are a priority, however, and emergency and intervening personnel should adhere to the established safety regulations and protect themselves against possible contamination from victims whilst offering all available medical resources and equipment⁴⁹⁻⁵². Therefore the station should include at least two decontamination lines, one for those who are not incapacitated (fit to walk) and another for incapacitated people (disabled and immobile people). With regard to the availability of resources, the possibility of setting up separate lines for men and women, which is the case in the Classification and Decontamination Stations of Nuclear Emergency Programmes could be analysed. Once again the

importance of creating NBC medical intervention units stands out⁵³.

This approach creates a need to establish NBC specific medical intervention units despite current opinions on the subject⁵⁴. These units should be capable of operating within the hot zone and should include an adequate level of individual protection because they will be trained to work in contaminated environments and carry out classification tasks (in order to establish an effective evacuation system) and set up treatment in the shortest amount of time^{55,56}. It is also necessary to study the legal possibility of introducing this practice which is normally carried out by the fire service. In general, we are used to the current state of affairs and because of legislation we have not considered the option⁵⁷⁻⁵⁹.

An additional question relates to transferring or evacuating those affected from the area of the incident (or impact zone) to the medical zone given that the exclusion distances from the hot zone to the warm zone are always over 50 metres (generally over 300 metres). Therefore, the rescue teams may be able to transport one or two casualties per stretcher but the odds are that one in ten will have to remain in the area of the incident for longer than they should because the rescue teams will be too tired to continue⁶⁰.

Another important issue that we should bear in mind is how the casualties of any kind of incident should be transferred to medical facilities. For each person that was taken by ambulance in Tokyo, 6 used their own transport means and

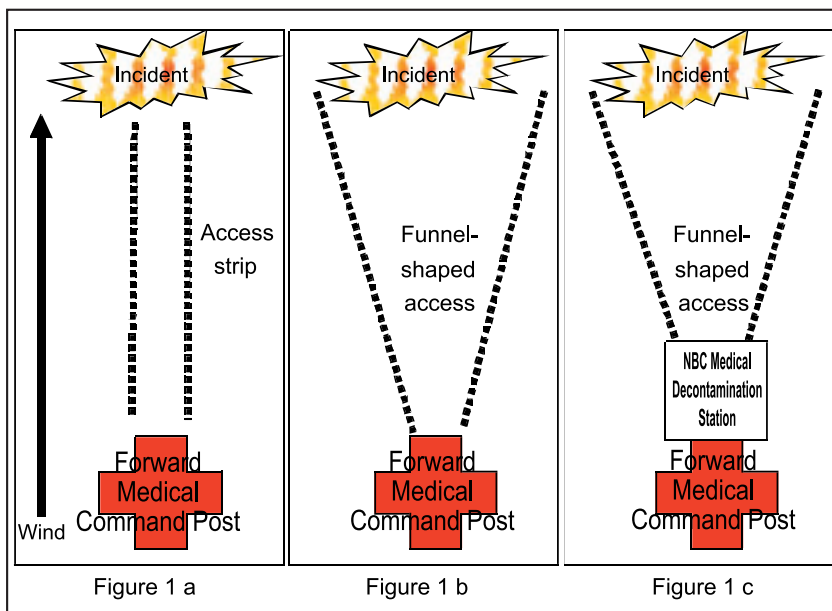


Figure 1. Different types of access channels to the medical zone.

subsequently contaminated the transport they used and the medical staff that treated them, who were not aware of what had happened⁶¹.

Therefore it became clear that a meeting point needed to be set up for affected individuals (known as the “injured nest” in military terms) located windward from the incident where the risk of contamination from vapour is lower because the air is cleaner compared to that of the incident or downwind from the accident. Here, casualties would be able to calm down, classification could take place (triage would also be undertaken if it had not been done previously in the area of the incident) and medical treatment would be set up⁶²⁻⁶⁴. It is necessary to assure onsite safety in order to prevent stress and panic breaking out among those affected⁶⁵. An evacuation circuit (contaminated) can be established at this meeting point until casualties can get to the NBC Medical Decontamination Station and the forward medical command post (Figure 2)⁶⁶.

This evacuation would be carried out using medicalised vehicles (or non-medicalised vehicles depending on the resources available) which would be covered in plastic sheeting. Alternatively, casualties could be transferred into the vehicles using isolation systems (NBC bags or isolation capsules) in order to reduce the level of contamination in the medicalised vehicle (or whatever vehicle is being used) (Figure 3)^{67,68}. The

vehicles used in this circuit should be decontaminated in a Vehicular Decontamination Station (Spanish Army NBC Unit support)⁶⁹.

As we have already mentioned, all those affected in an NBC incident are contaminated and therefore a meeting point must be set up before they enter the NBC Medical Decontamination Station in order to verify whether they are really contaminated or not⁷⁰. This is of utmost importance when establishing a medical intervention strategy given that the NBC Medical Decontamination Station can only treat a limited number of people. Water and decontaminants are also crucial resources and furthermore staff need time to rest, therefore contamination control is essential⁷¹. The main advantage associated with setting up this control system is that it reduces the number of people that have to pass through the decontamination station and this prevents it from collapsing. People who may have symptoms but may not be contaminated (psychosomatic casualties)^{72,73} and also injured individuals who are not contaminated would not have to pass through the decontamination station^{74,75}. Contamination control implies creating a corridor so that injured individuals or psychosomatic casualties can reach the forward medical command post in order to be treated (Figure 4a) It also creates the need for a team of stretcher bearers who can transfer no fewer than 2 non-contaminated immobile casualties at a time.

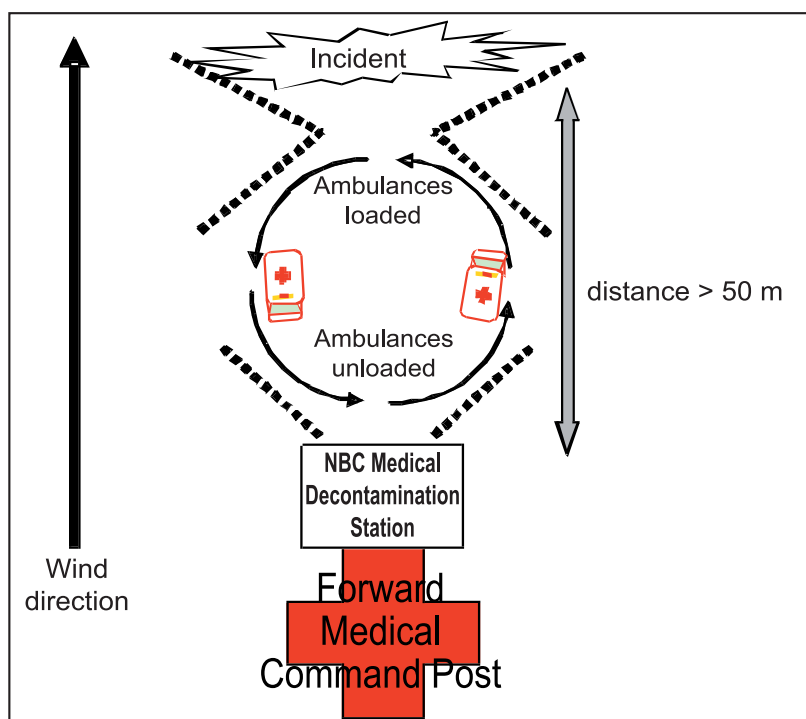


Figure 2. The contaminated evacuation circuit.



Figure 3. The inside surfaces of the vehicle are covered in order to reduce the risk of contamination.

By setting up contamination control and bringing together in one place all those who are affected and who need to reach the medical zone, we are able to monitor their movements. At times it will be impossible to group everyone together efficiently because communication between the intervening personnel and the casualties is too difficult. However an alphanumeric or bar code identification system could be established for all those affected by writing a code on visible parts of the body like the hands or forehead, or using a sticker made of

decontaminable material and a designation system that cannot be manipulated.

At certain times when an NBC incident produces a large number of casualties, the capacity of the decontamination station may be overstretched and for that reason, an area that precedes the entrance to the station where emergency treatment can be given (oxygenation, resuscitation and administering antidotes if available), immediate decontamination can take place and the casualties who need to be decontaminated by

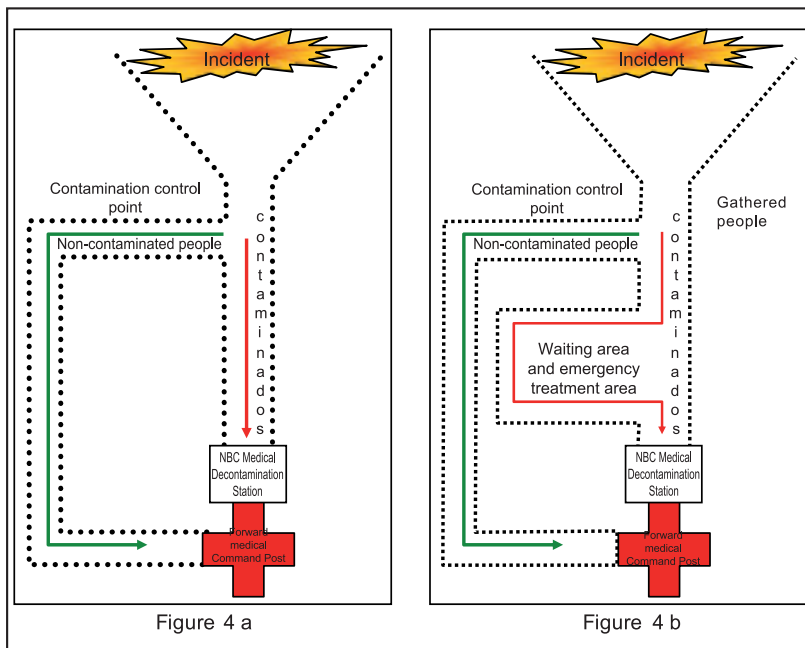


Figure 4. The non-contaminated corridor and emergency treatment area.

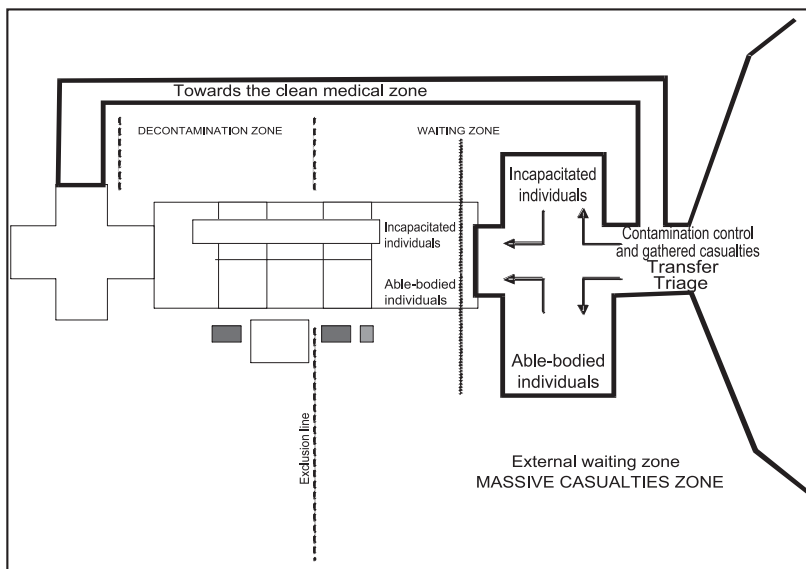


Figure 5. The organisation of the medical zone in NBC incidents.

medical staff who have the appropriate level of individual protection and the right training can be stabilised is needed (Figure 4b)⁷⁶⁻⁸¹.

The level of medical care in the emergency treatment area depends on the facilities and resources that are available⁸². This should be analysed from an ethical viewpoint given that if capacity is overstretched, the classification criteria should be changed from “emergency” to multiple victim criteria classification (the military term is massive casualties)⁸³⁻⁸⁵.

This system can be improved by using the emergency treatment station in two different zones (in the same way it is used in the decontamination station).

One is for able-bodied casualties and the other for incapacitated casualties with, the positioning of these zones being established in relation to the different areas of the station. The organisation of individuals in the emergency treatment room depends on the classification of the affected individuals and the station entry order (Figure 5)^{49,86}.

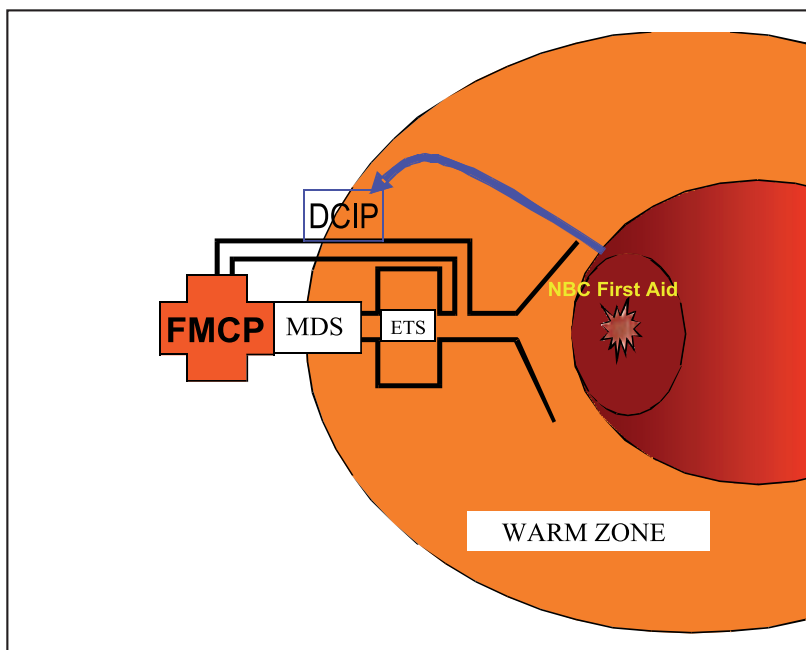


Figure 6. The positioning of the Decontamination Centre for Intervening Personnel and the NBC Medical Decontamination Station. FMCP: forward medical Command Post. MDS: NBC Medical Decontamination Station. ETS: Emergency Treatment Station.



A crucial aspect of a NBC incident is integrating the different emergency organisations and services that have been called on to respond to the accident. The main problem faced (or more specifically, the main problem the chief of operations faces) is how to take advantage of the warm zone and how to respect the areas where the emergency services are based given that each service has its own special requirements regarding materials and resources. For example, the police and fire service need different decontamination facilities which are commonly known as Intervening Personnel Decontamination Centres or Stations. These facilities should be different from the NBC Medical Decontamination Centre given that their structure, design and function are distinct (Figure 6).

CONCLUSION

The emergency services need to establish standardised operating protocols in order to improve intervention.

The different sets of terminology used by the emergency services must also be standardised for more efficient intervention and to consolidate protocol.

If the area where medical units are based is organised correctly this will be highly beneficial for the affected individuals in a NBC incident. In order to achieve this, NBC medical intervention units that can operate in contaminated areas need to be set up. These units should be trained and should have all the necessary materials and equipment at their disposal. They should also be integrated into a hierarchy and should be familiar with all the NBC incident-specific operating procedures and protocols.

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